

# A first look at the mass spectra with neural network eID

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HBD meeting

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# Neural network optimization

- Lessons learned:
  - pt or mom not a good variable – NN will make a bias when trying to remove background
  - Bbc charge not a good variable – NN will make a bias in centralities
  - separately removing hadrons and backplane conversions gives worse results, than training the NN to remove both of them as the background
  - Using more HBD information (charge, charge/size, hbddphi, hbddz, maxpadcharge...) improves the results in HIJING, but one needs to tune DATA and HIJING before applying it

# Neural network details

- NN\_v102
- The following cuts are applied before NN:
  - EWG cuts:
    - $n0>1 \mid\mid sn0>1$
    - $E/p>0.4 \&\& E/p<10$
    - $nx1hits>0 \&\& nx2hits>0$
  - $pT>0.2$  GeV/c
  - HBD projection cuts
  - HBD support construction cuts
  - HBD matching:

Centrality	Rejection (hbdid)	Efficiency (s.e.)
0-10	8	71%
10-20	9	77%
20-30	10	84%
30-40	11	89%
40-50	15	90%
50-100	20	>90%

# Neural network details

- Trained on HIJING events
- Excluding  $\pi^0$  signal (which is ~80% of the signal)
- Centrality bins (available statistics):
  - 0-10%: 33k tracks (1k signal, 23k hadrons, 1.5k beampipe, 3k gas, 4.5k backplane)
  - 10-20%: 17k tracks (0.8k signal, 10k hadrons, 1k beampipe, 2k gas, 2.5k backplane)
  - 20-40%: 15k tracks (1k signal, 7.5k hadrons, 1.5k beampipe, 2.7k gas, 2.5k backplane)
  - 40-60%: 22k tracks (2.5k signal, 6k hadrons, 4k beampipe, 7.5k gas, 2.4k backplane)
  - 50-100%: 13k tracks (1.8k signal, 1.8k hadrons, 3k beampipe, 5.6k gas, 1k backplane)
- Input variables: E/p, prob, n0, chi2/npe0, disp,  
hbdid (MinPad), hbdsize (WisCl)
- Output:
  - Background = hadrons + backplane conversions
  - Signal != Background

# Compare elD cuts in HIJING

CA+HBD eID	Cent	Tracks /100e	Signal /100e	Hadrons /100e	BCKPLs /100e	Hadr. Rej.	BCKPL sRej.	Hadrs/ Signal	Sig trk. effic.
	<b>0-10 %</b>	30.6	8.5	5.1	5.3	95	20	<b>0.59</b>	<b>0.27</b>
	<b>10-20%</b>	21.6	7.0	2.3	5.2	100	20	<b>0.32</b>	<b>0.31</b>
	<b>20-40%</b>	12.0	4.6	0.7	2.2	95	30	<b>0.18</b>	<b>0.36</b>
	<b>40-60%</b>	4.5	2.1	0.09	0.39	140	65	<b>0.04</b>	<b>0.41</b>
	<b>60-92%</b>	0.7	0.36	0.004	0.021	130	210	<b>0.01</b>	<b>0.42</b>

NN eID (@MAX FOM)	Cent	Tracks /100e	Signal /100e	Hadrons /100e	BCKPLs /100e	Hadr. Rej.	BCKPL sRej.	Hadrs/ Signal	Sig trk. effic.
	<b>0-10 %</b>	32.5	10.4	5.6	3.8	85	25	<b>0.54</b>	<b>0.31</b>
	<b>10-20%</b>	21.7	8.4	2.3	2.7	90	40	<b>0.28</b>	<b>0.37</b>
	<b>20-40%</b>	12.6	5.6	0.7	1.1	95	60	<b>0.15</b>	<b>0.45</b>
	<b>40-60%</b>	5.3	2.6	0.10	0.23	125	115	<b>0.04</b>	<b>0.50</b>
	<b>60-92%</b>	1.0	0.49	0.006	0.023	90	195	<b>0.01</b>	<b>0.56</b>

# Using NN with data

- Using good runs, from Stony Brook QA
- 5 groups with similar dead area map:

See tables in backup slides for details

- Total number of events 5.58B events
- RunG1, 132 runs, 512M events
- RunG2, 221 runs, 1.36B events
- RunG3, 188 runs, 1.50B events
- RunG4, 99 runs, 758M events
- RunG5, 106 runs, 681M events
- Rich probem, 45 runs, 336M events
- Bad runs, 95 runs, 437M events

From Ermias's presentation

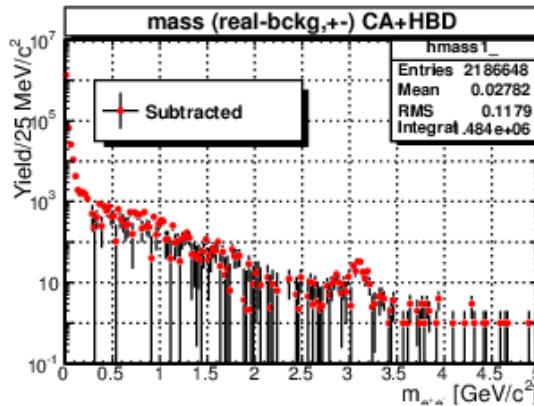
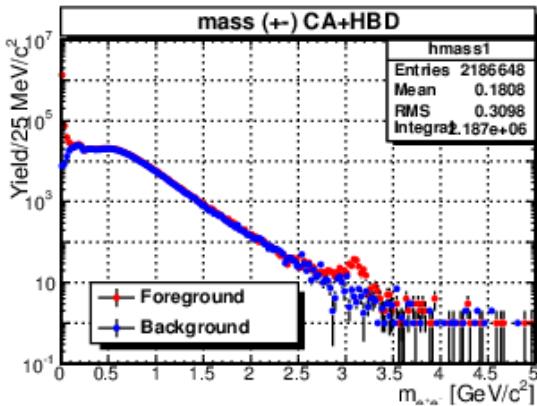
Total 4.8B events

# The next slides

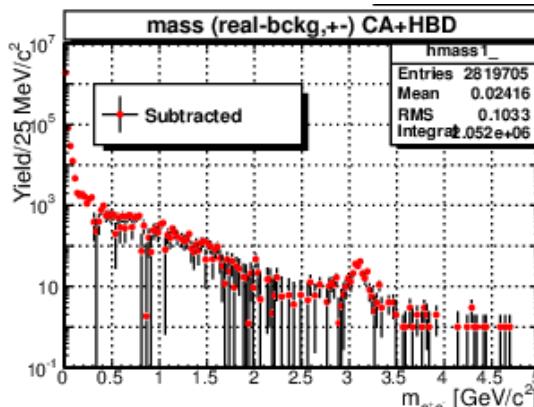
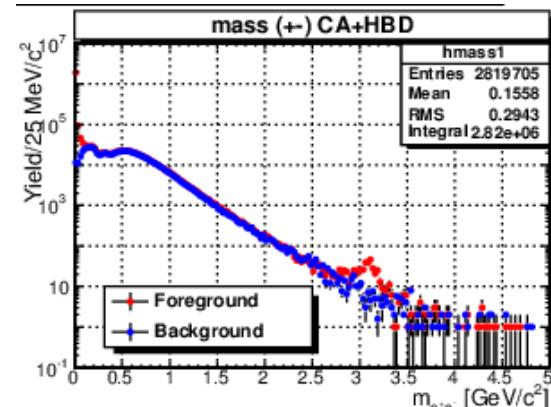
- Mass spectra, constant bin size (25 MeV)
- Analyzed in run groups
- Analyzed in different centrality bins
- Like-sign method
- Akiba pool
- Corrected for acceptance in ( $m, p_T$ ) bins (zvertex binning not applied)

# Compare mass spectra

Centrality: 40-100%



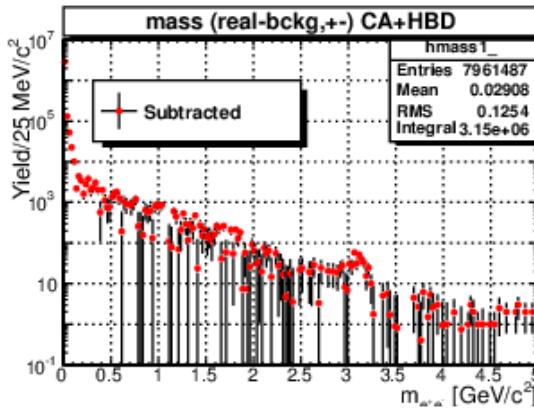
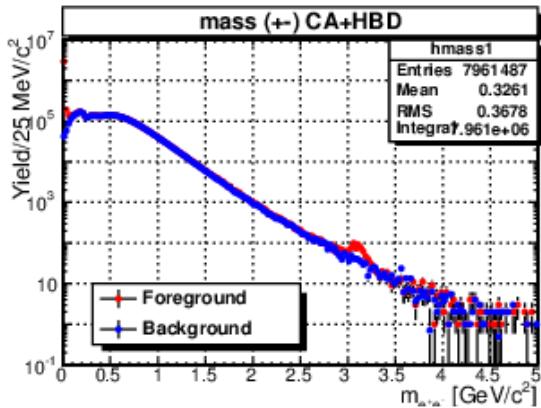
CA+HBD	
B/S (m>0.15 GeV/c <sup>2</sup> )	<b>30</b>
Sign. (m>0.15 GeV/c <sup>2</sup> )	<b>20368 +/- 795</b>
Eff. Sign. (m>0.15 GeV/c <sup>2</sup> )	<b>334 +/- 13</b>
B/S (m<0.15 GeV/c <sup>2</sup> )	0.06
Sign. (m<0.15 GeV/c <sup>2</sup> )	1.465e6 +/- 1247
Eff. Sign. (m<0.15 GeV/c <sup>2</sup> )	1.302e6 +/- 1110
Yield in (2.8-3.4 GeV/c <sup>2</sup> )	273 +/- 20



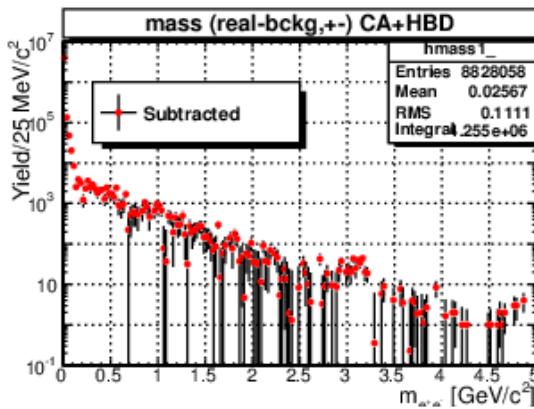
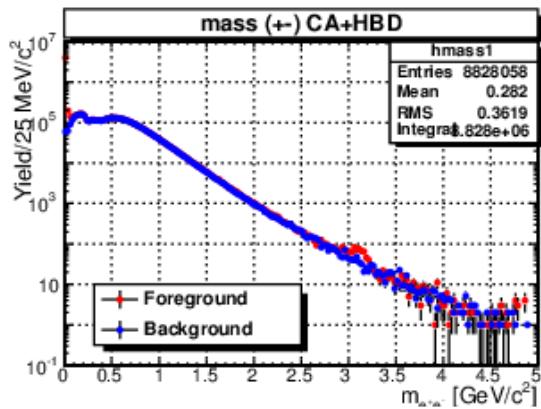
NN_v102	
B/S (m>0.15 GeV/c <sup>2</sup> )	<b>25</b>
Sign. (m>0.15 GeV/c <sup>2</sup> )	<b>24925 +/- 809</b>
Eff. Sign. (m>0.15 GeV/c <sup>2</sup> )	<b>466 +/- 15</b>
B/S (m<0.15 GeV/c <sup>2</sup> )	0.06
Sign. (m<0.15 GeV/c <sup>2</sup> )	2.027e6 +/- 1463
Eff. Sign. (m<0.15 GeV/c <sup>2</sup> )	1.822e6 +/- 1316
Yield in (2.8-3.4 GeV/c <sup>2</sup> )	308 +/- 22

# Compare mass spectra

Centrality: 20-40%



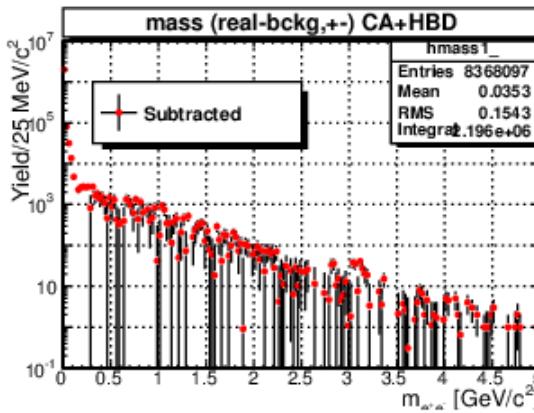
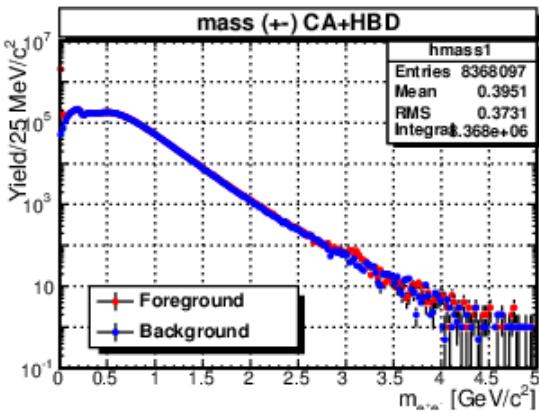
CA+HBD	
B/S ( $m > 0.15$ GeV/ $c^2$ )	75
Sign. ( $m > 0.15$ GeV/ $c^2$ )	55355 +/- 2070
Eff. Sign. ( $m > 0.15$ GeV/ $c^2$ )	360 +/- 13
B/S ( $m < 0.15$ GeV/ $c^2$ )	0.2
Sign. ( $m < 0.15$ GeV/ $c^2$ )	3.095e6 +/- 1916
Eff. Sign. ( $m < 0.15$ GeV/ $c^2$ )	2.249e6 +/- 1393
Yield in (2.8-3.4 GeV/ $c^2$ )	407 +/- 37



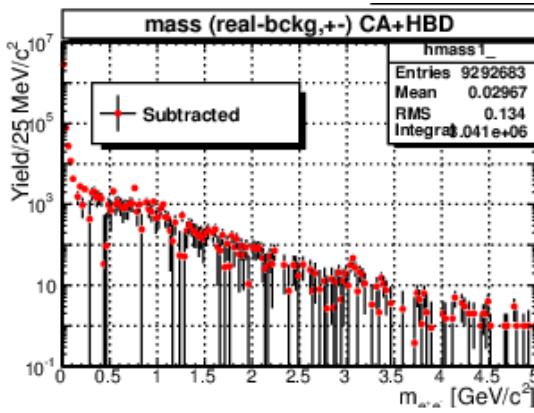
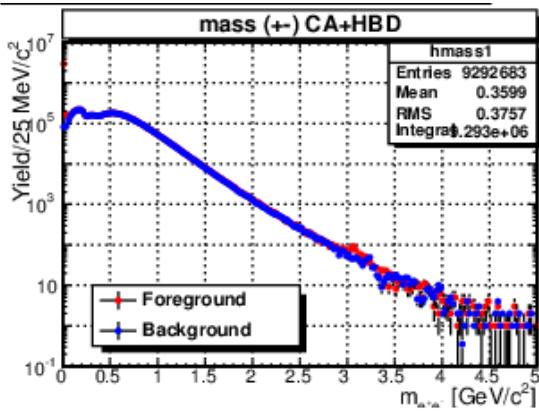
NN_v102	
B/S ( $m > 0.15$ GeV/ $c^2$ )	65
Sign. ( $m > 0.15$ GeV/ $c^2$ )	59751 +/- 2002
Eff. Sign. ( $m > 0.15$ GeV/ $c^2$ )	449 +/- 15
B/S ( $m < 0.15$ GeV/ $c^2$ )	0.15
Sign. ( $m < 0.15$ GeV/ $c^2$ )	4.195e6 +/- 2196
Eff. Sign. ( $m < 0.15$ GeV/ $c^2$ )	3.229e6 +/- 1690
Yield in (2.8-3.4 GeV/ $c^2$ )	354 +/- 36

# Compare mass spectra

Centrality: 10-20%



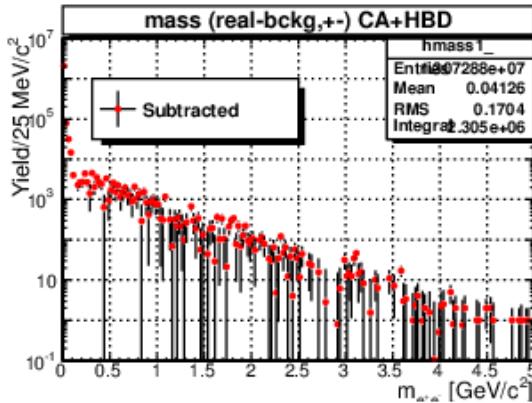
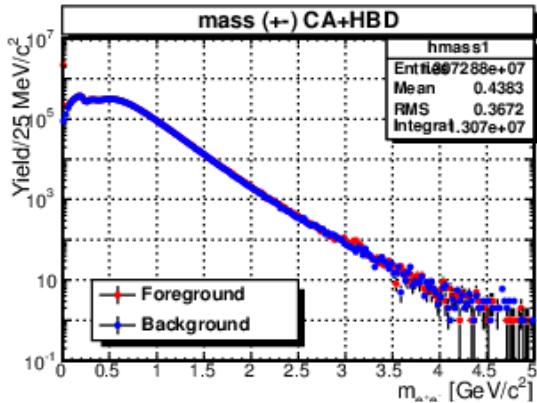
CA+HBD	
B/S (m>0.15 GeV/c <sup>2</sup> )	110
Sign. (m>0.15 GeV/c <sup>2</sup> )	48776 +/- 2342
Eff. Sign. (m>0.15 GeV/c <sup>2</sup> )	218 +/- 11
B/S (m<0.15 GeV/c <sup>2</sup> )	0.35
Sign. (m<0.15 GeV/c <sup>2</sup> )	2.147e6 +/- 1698
Eff. Sign. (m<0.15 GeV/c <sup>2</sup> )	1.274e6 +/- 1007
Yield in (2.8-3.4 GeV/c <sup>2</sup> )	322 +/- 37



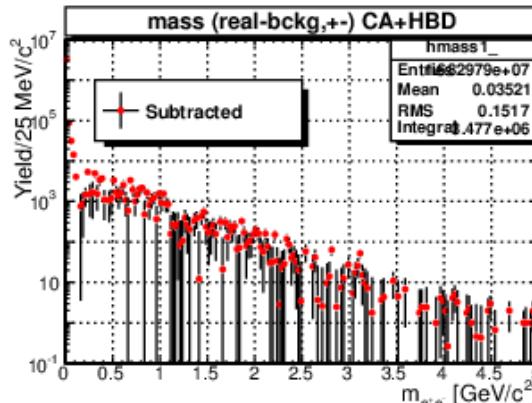
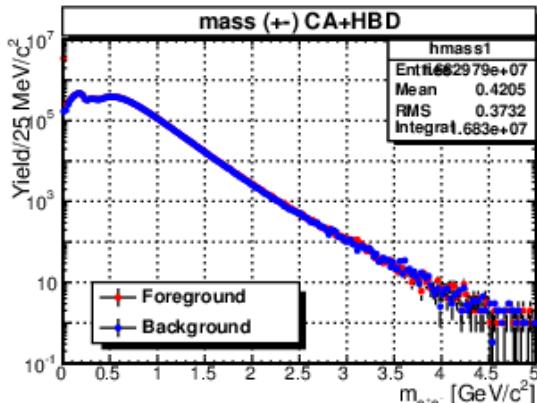
NN_v102	
B/S (m>0.15 GeV/c <sup>2</sup> )	120
Sign. (m>0.15 GeV/c <sup>2</sup> )	44409 +/- 2336
Eff. Sign. (m>0.15 GeV/c <sup>2</sup> )	181 +/- 9
B/S (m<0.15 GeV/c <sup>2</sup> )	0.28
Sign. (m<0.15 GeV/c <sup>2</sup> )	3.000e6 +/- 1958
Eff. Sign. (m<0.15 GeV/c <sup>2</sup> )	1.921e6 +/- 1256
Yield in (2.8-3.4 GeV/c <sup>2</sup> )	268 +/- 38

# Compare mass spectra

Centrality: 0-10%



CA+HBD	
B/S (m>0.15 GeV/c <sup>2</sup> )	<b>130</b>
Sign. (m>0.15 GeV/c <sup>2</sup> )	<b>72563 +/- 3092</b>
Eff. Sign. (m>0.15 GeV/c <sup>2</sup> )	<b>276 +/- 12</b>
B/S (m<0.15 GeV/c <sup>2</sup> )	0.6
Sign. (m<0.15 GeV/c <sup>2</sup> )	2.233e6 +/- 1874
Eff. Sign. (m<0.15 GeV/c <sup>2</sup> )	1.041e6 +/- 873
Yield in (2.8-3.4 GeV/c <sup>2</sup> )	140 +/- 43



NN_v102	
B/S (m>0.15 GeV/c <sup>2</sup> )	<b>160</b>
Sign. (m>0.15 GeV/c <sup>2</sup> )	<b>73022 +/- 3414</b>
Eff. Sign. (m>0.15 GeV/c <sup>2</sup> )	<b>229 +/- 11</b>
B/S (m<0.15 GeV/c <sup>2</sup> )	0.52
Sign. (m<0.15 GeV/c <sup>2</sup> )	3.404e6 +/- 2275
Eff. Sign. (m<0.15 GeV/c <sup>2</sup> )	1.668e6 +/- 1115
Yield in (2.8-3.4 GeV/c <sup>2</sup> )	158 +/- 49

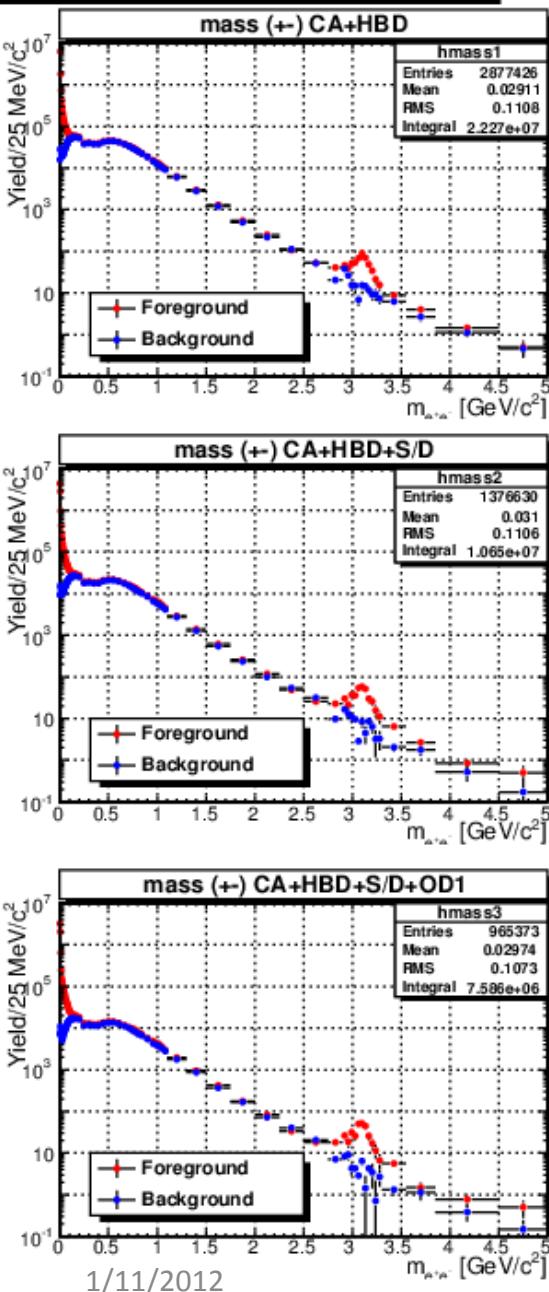
# The Next Slides

- Neural Network results
- Analyzed in run groups
- Analyzed in different centrality bins
- Like-sign method
- Akiba pool

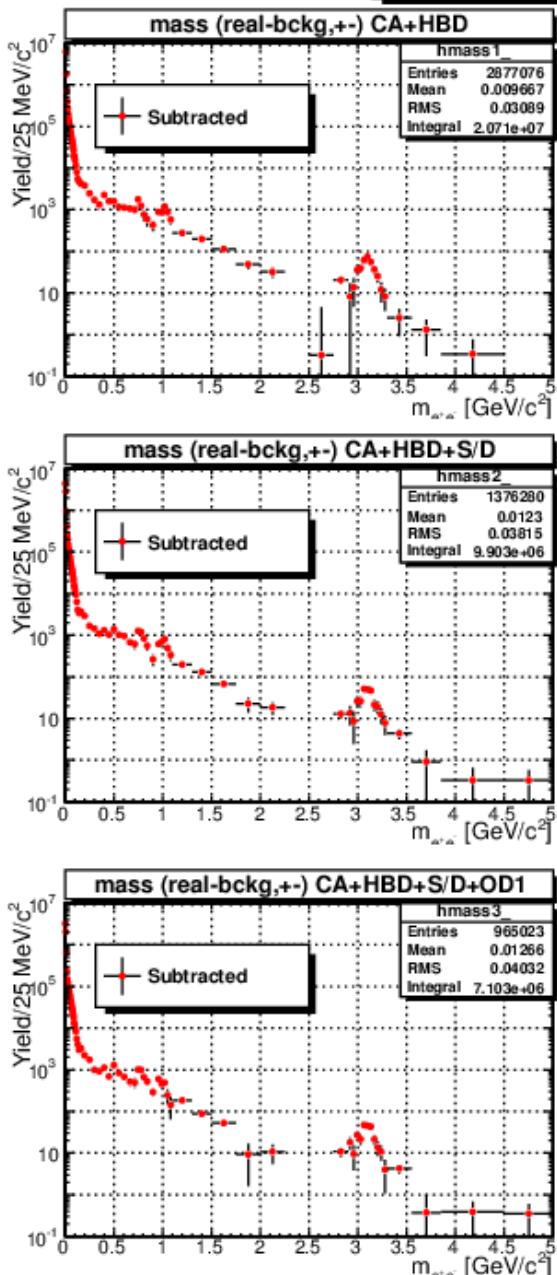
Different than previous:

- Acceptance correction in  $(m, pt, bbcz)$  bins
- Variable bin sizes
- S/D rejection
- Label on Y axis should be Yield per  $50 \text{ MeV}/c^2$ !

# NN\_v102

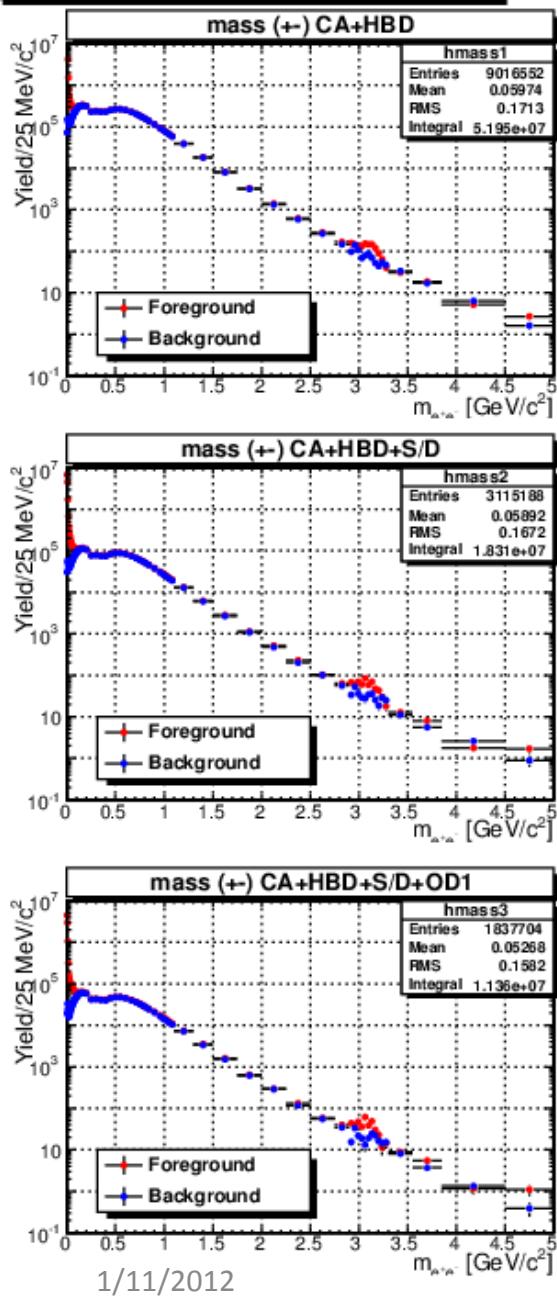


40 < Centrality < 100

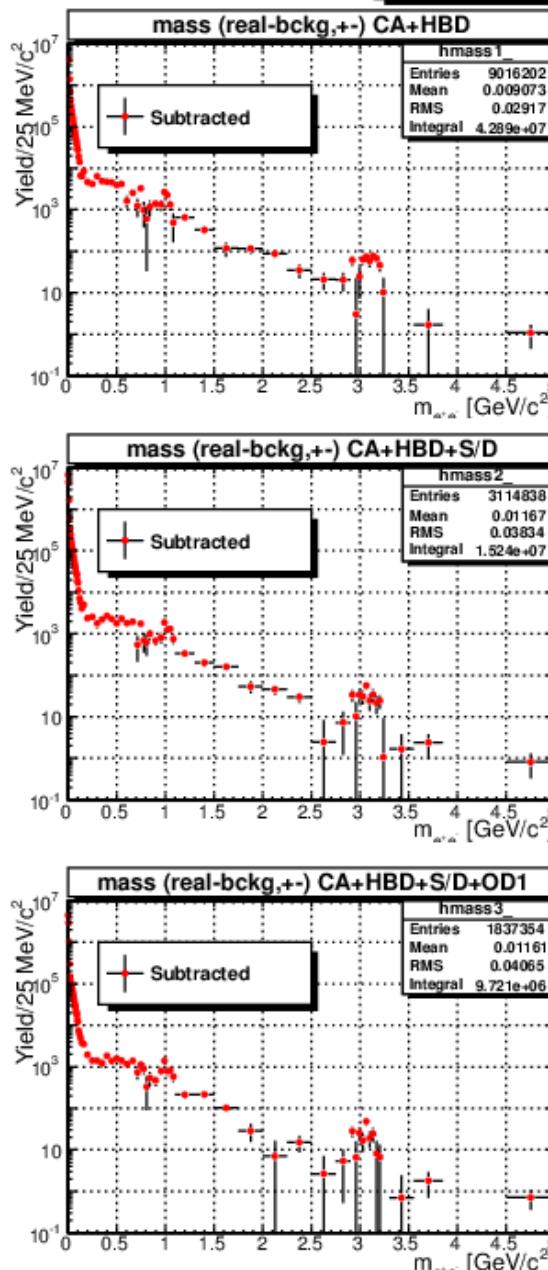


B/S ( $m>0.15 \text{ GeV}/c^2$ )	21
Sign. ( $m>0.15 \text{ GeV}/c^2$ )	<b>30831 +/- 832</b>
Eff. Sign. ( $m>0.15 \text{ GeV}/c^2$ )	<b>701 +/- 19</b>
B/S ( $m<0.15 \text{ GeV}/c^2$ )	0.055
Sign. ( $m<0.15 \text{ GeV}/c^2$ )	$2.071\text{e}6 +/- 1\text{e}3$
Eff. Sign. ( $m<0.15 \text{ GeV}/c^2$ )	$1.868\text{e}6 +/- 1\text{e}3$
Yield in ( $2.9\text{-}3.3 \text{ GeV}/c^2$ )	$262 +/- 20$
B/S ( $m>0.15 \text{ GeV}/c^2$ )	14
Sign. ( $m>0.15 \text{ GeV}/c^2$ )	<b>22848 +/- 575</b>
Eff. Sign. ( $m>0.15 \text{ GeV}/c^2$ )	<b>817 +/- 21</b>
B/S ( $m<0.15 \text{ GeV}/c^2$ )	0.050
Sign. ( $m<0.15 \text{ GeV}/c^2$ )	$0.990\text{e}6 +/- 1\text{e}3$
Eff. Sign. ( $m<0.15 \text{ GeV}/c^2$ )	$0.891\text{e}6 +/- 1\text{e}3$
Yield in ( $2.9\text{-}3.3 \text{ GeV}/c^2$ )	$202 +/- 16$
B/S ( $m>0.15 \text{ GeV}/c^2$ )	11
Sign. ( $m>0.15 \text{ GeV}/c^2$ )	<b>18569 +/- 468</b>
Eff. Sign. ( $m>0.15 \text{ GeV}/c^2$ )	<b>823 +/- 21</b>
B/S ( $m<0.15 \text{ GeV}/c^2$ )	0.06
Sign. ( $m<0.15 \text{ GeV}/c^2$ )	$0.711\text{e}6 +/- 1\text{e}3$
Eff. Sign. ( $m<0.15 \text{ GeV}/c^2$ )	$0.646\text{e}6 +/- 1\text{e}3$
Yield in ( $2.9\text{-}3.3 \text{ GeV}/c^2$ )	$185 +/- 15$
	13

# NN\_v102

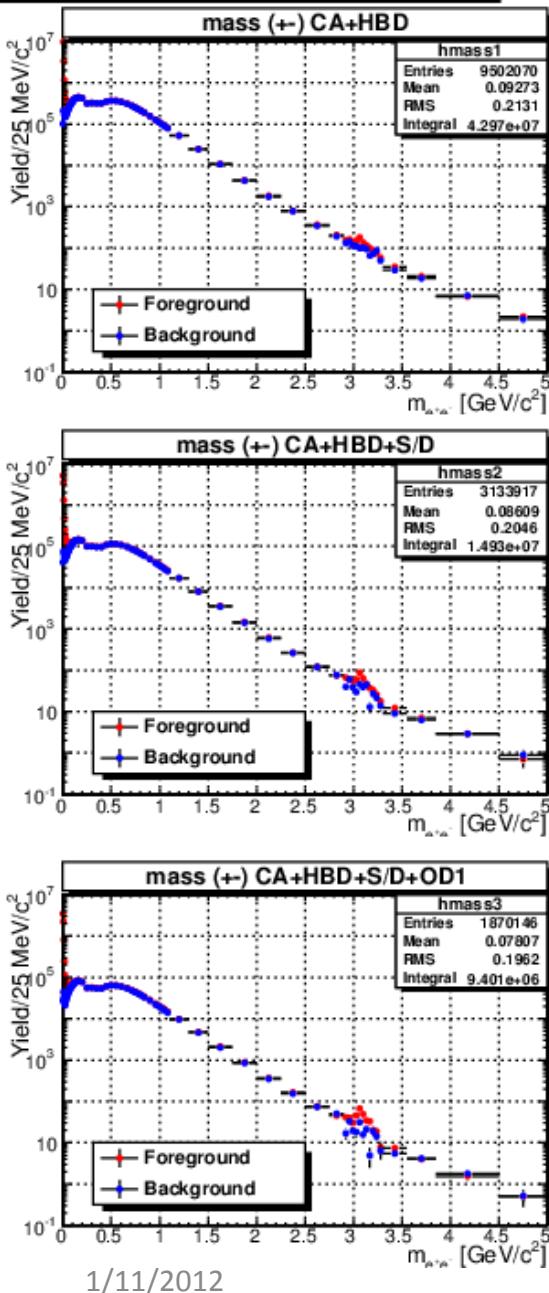


20 < Centrality < 40

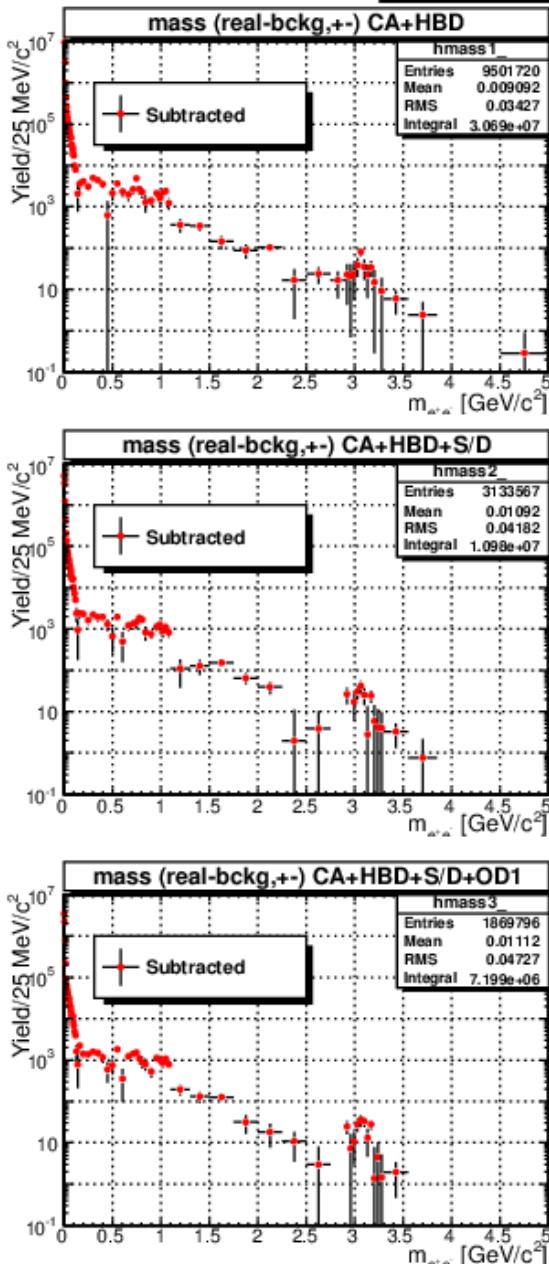


B/S (m>0.15 GeV/c <sup>2</sup> )	60
Sign. (m>0.15 GeV/c <sup>2</sup> )	<b>65159 +/- 2023</b>
Eff. Sign. (m>0.15 GeV/c <sup>2</sup> )	<b>553 +/- 16</b>
B/S (m<0.15 GeV/c <sup>2</sup> )	0.15
Sign. (m<0.15 GeV/c <sup>2</sup> )	4.287e6 +/- 2e3
Eff. Sign. (m<0.15 GeV/c <sup>2</sup> )	3.307e6 +/- 1e3
Yield in (2.9-3.3 GeV/c <sup>2</sup> )	341 +/- 31
B/S (m>0.15 GeV/c <sup>2</sup> )	35
Sign. (m>0.15 GeV/c <sup>2</sup> )	<b>36704 +/- 1171</b>
Eff. Sign. (m>0.15 GeV/c <sup>2</sup> )	<b>498 +/- 16</b>
B/S (m<0.15 GeV/c <sup>2</sup> )	0.15
Sign. (m<0.15 GeV/c <sup>2</sup> )	1.523e6 +/- 1e3
Eff. Sign. (m<0.15 GeV/c <sup>2</sup> )	1.181e6 +/- 1e3
Yield in (2.9-3.3 GeV/c <sup>2</sup> )	186 +/- 21
B/S (m>0.15 GeV/c <sup>2</sup> )	30
Sign. (m>0.15 GeV/c <sup>2</sup> )	<b>25572 +/- 865</b>
Eff. Sign. (m>0.15 GeV/c <sup>2</sup> )	<b>444 +/- 15</b>
B/S (m<0.15 GeV/c <sup>2</sup> )	0.12
Sign. (m<0.15 GeV/c <sup>2</sup> )	0.972 +/- 1e3
Eff. Sign. (m<0.15 GeV/c <sup>2</sup> )	0.784e6 +/- 1e3
Yield in (2.9-3.3 GeV/c <sup>2</sup> )	129 +/- 17 14

# NN v102

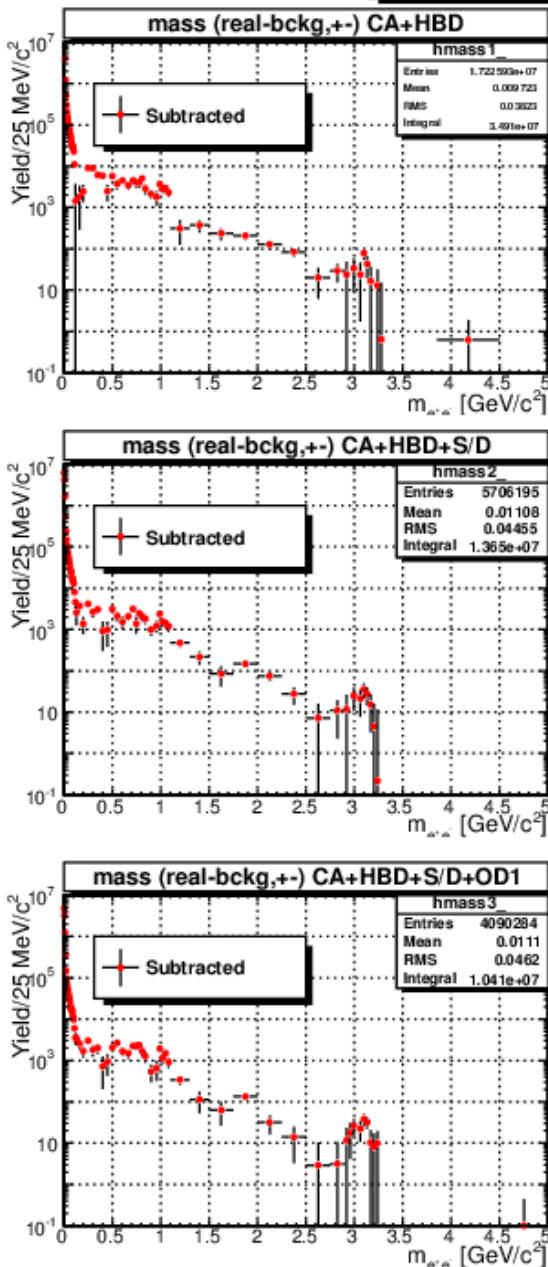
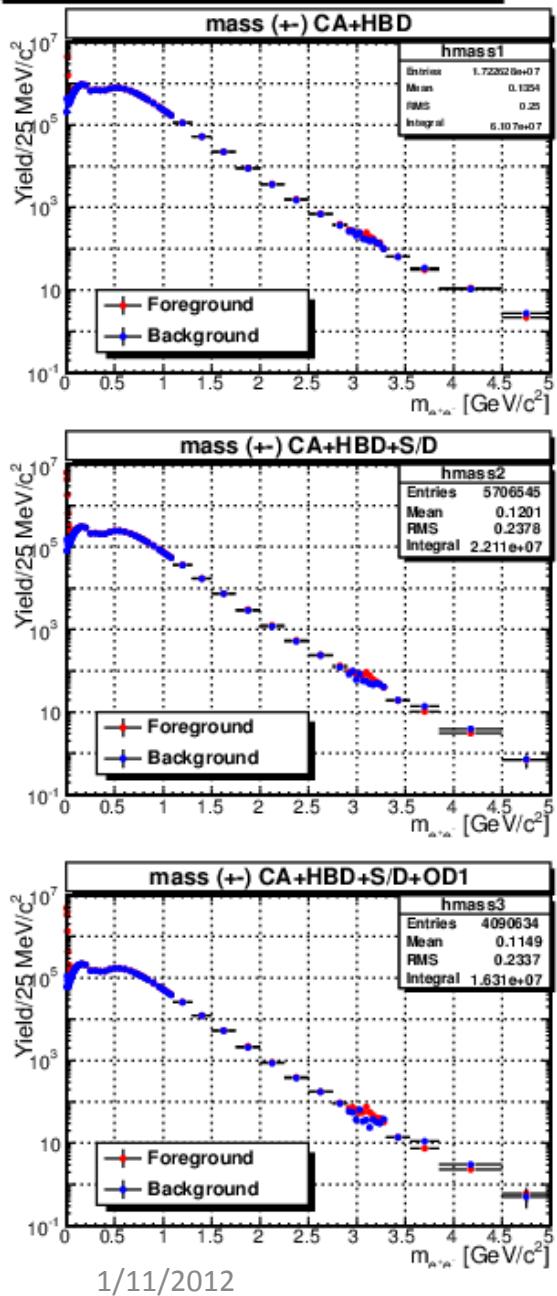


10 < Centrality < 20



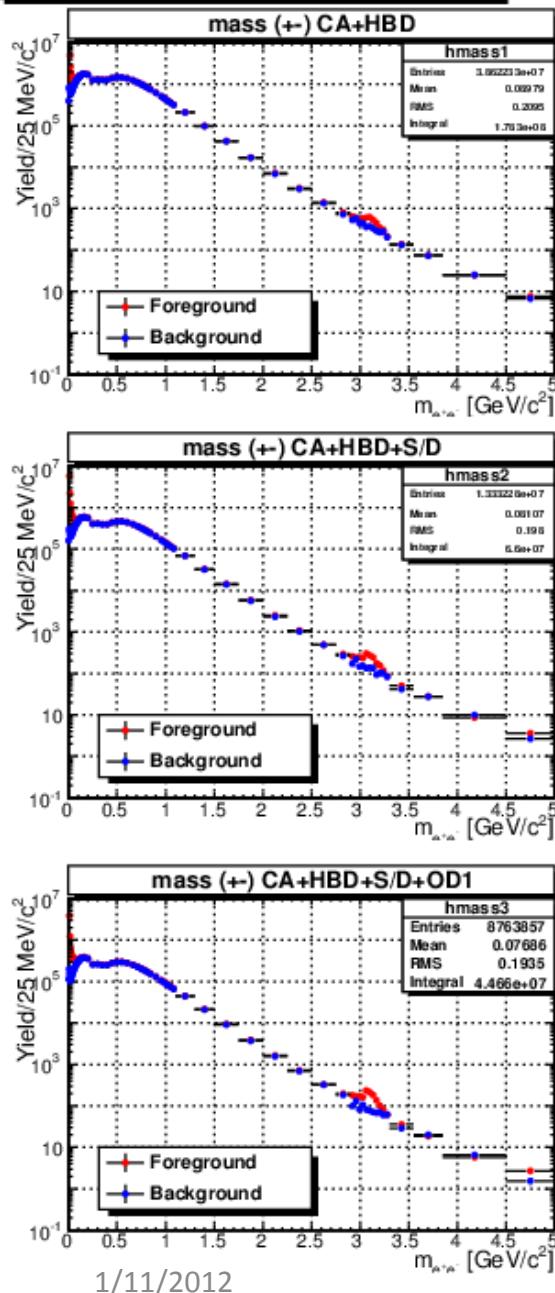
B/S (m>0.15 GeV/c <sup>2</sup> )	100
Sign. (m>0.15 GeV/c <sup>2</sup> )	<b>55581 +/- 2363</b>
Eff. Sign. (m>0.15 GeV/c <sup>2</sup> )	<b>278 +/- 12</b>
B/S (m<0.15 GeV/c <sup>2</sup> )	0.29
Sign. (m<0.15 GeV/c <sup>2</sup> )	3.065e6 +/- 2e3
Eff. Sign. (m<0.15 GeV/c <sup>2</sup> )	1.970e6 +/- 1e3
Yield in (2.9-3.3 GeV/c <sup>2</sup> )	209 +/- 31
B/S (m>0.15 GeV/c <sup>2</sup> )	60
Sign. (m>0.15 GeV/c <sup>2</sup> )	<b>28742 +/- 1325</b>
Eff. Sign. (m>0.15 GeV/c <sup>2</sup> )	<b>237 +/- 11</b>
B/S (m<0.15 GeV/c <sup>2</sup> )	0.26
Sign. (m<0.15 GeV/c <sup>2</sup> )	1.096e6 +/- 1e3
Eff. Sign. (m<0.15 GeV/c <sup>2</sup> )	0.725e6 +/- 1e3
Yield in (2.9-3.3 GeV/c <sup>2</sup> )	131 +/- 20
B/S (m>0.15 GeV/c <sup>2</sup> )	40
Sign. (m>0.15 GeV/c <sup>2</sup> )	<b>23280 +/- 997</b>
Eff. Sign. (m>0.15 GeV/c <sup>2</sup> )	<b>276 +/- 12</b>
B/S (m<0.15 GeV/c <sup>2</sup> )	0.22
Sign. (m<0.15 GeV/c <sup>2</sup> )	0.719 +/- 1e3
Eff. Sign. (m<0.15 GeV/c <sup>2</sup> )	0.501e6 +/- 1e3
Yield in (2.9-3.3 GeV/c <sup>2</sup> )	133 +/- 17

# NN\_v102

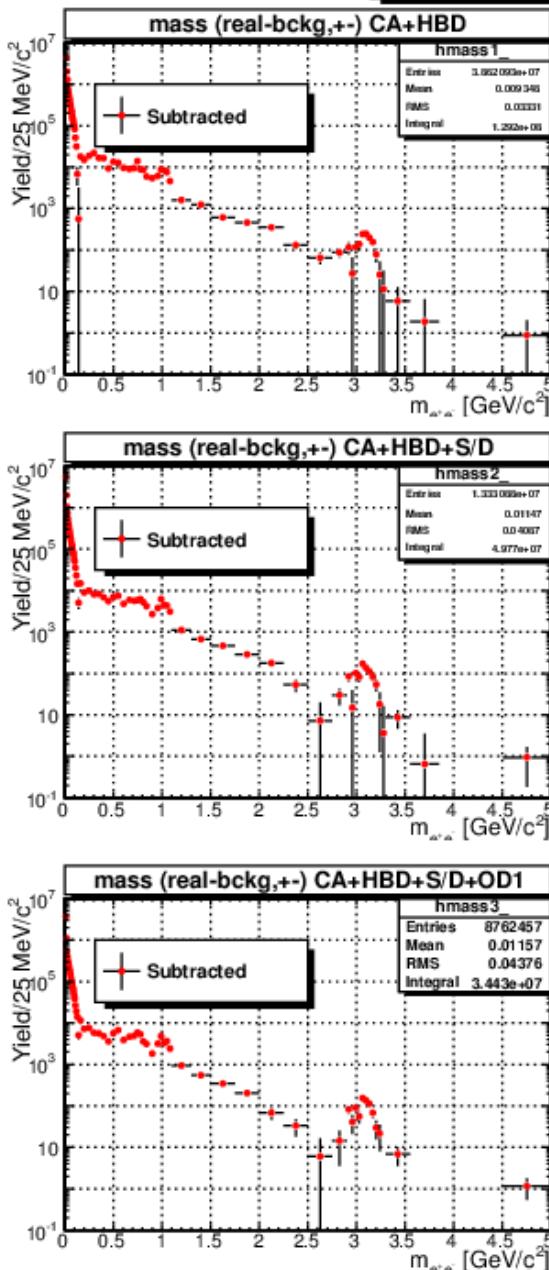


B/S ( $m > 0.15 \text{ GeV}/c^2$ )	<b>135</b>
Sign. ( $m > 0.15 \text{ GeV}/c^2$ )	<b>86639 +/- 3455</b>
Eff. Sign. ( $m > 0.15 \text{ GeV}/c^2$ )	<b>316 +/- 16</b>
B/S ( $m < 0.15 \text{ GeV}/c^2$ )	0.5
Sign. ( $m < 0.15 \text{ GeV}/c^2$ )	3.478e6 +/- 2e3
Eff. Sign. ( $m < 0.15 \text{ GeV}/c^2$ )	1.706e6 +/- 1e3
Yield in (2.9-3.3 $\text{GeV}/c^2$ )	150 +/- 40
B/S ( $m > 0.15 \text{ GeV}/c^2$ )	<b>85</b>
Sign. ( $m > 0.15 \text{ GeV}/c^2$ )	<b>43008 +/- 2e3</b>
Eff. Sign. ( $m > 0.15 \text{ GeV}/c^2$ )	<b>248 +/- 11</b>
B/S ( $m < 0.15 \text{ GeV}/c^2$ )	0.45
Sign. ( $m < 0.15 \text{ GeV}/c^2$ )	1.362e6 +/- 1e3
Eff. Sign. ( $m < 0.15 \text{ GeV}/c^2$ )	0.724e6 +/- 1e3
Yield in (2.9-3.3 $\text{GeV}/c^2$ )	92 +/- 24
B/S ( $m > 0.15 \text{ GeV}/c^2$ )	<b>75</b>
Sign. ( $m > 0.15 \text{ GeV}/c^2$ )	<b>34247 +/- 2e3</b>
Eff. Sign. ( $m > 0.15 \text{ GeV}/c^2$ )	<b>224 +/- 11</b>
B/S ( $m < 0.15 \text{ GeV}/c^2$ )	0.40
Sign. ( $m < 0.15 \text{ GeV}/c^2$ )	1.035e6 +/- 1e6
Eff. Sign. ( $m < 0.15 \text{ GeV}/c^2$ )	0.574e6 +/- 1e6
Yield in (2.9-3.3 $\text{GeV}/c^2$ )	112 +/- 21

# NN v102



## 0 < Centrality < 100



B/S ( $m>0.15 \text{ GeV}/c^2$ )	90
Sign. ( $m>0.15 \text{ GeV}/c^2$ )	<b>238209 +/- 4723</b>
Eff. Sign. ( $m>0.15 \text{ GeV}/c^2$ )	<b>1279 +/- 25</b>
B/S ( $m<0.15 \text{ GeV}/c^2$ )	0.25
Sign. ( $m<0.15 \text{ GeV}/c^2$ )	1.290e7 +/- 4e3
Eff. Sign. ( $m<0.15 \text{ GeV}/c^2$ )	8.442e6 +/- 3e3
Yield in (2.9-3.3 $\text{GeV}/c^2$ )	963 +/- 63
B/S ( $m>0.15 \text{ GeV}/c^2$ )	55
Sign. ( $m>0.15 \text{ GeV}/c^2$ )	<b>131302 +/- 2475</b>
Eff. Sign. ( $m>0.15 \text{ GeV}/c^2$ )	<b>1208 +/- 25</b>
B/S ( $m<0.15 \text{ GeV}/c^2$ )	0.23
Sign. ( $m<0.15 \text{ GeV}/c^2$ )	4.971e6 +/- 2e3
Eff. Sign. ( $m<0.15 \text{ GeV}/c^2$ )	3.393e6 +/- 2e3
Yield in (2.9-3.3 $\text{GeV}/c^2$ )	611 +/- 41
B/S ( $m>0.15 \text{ GeV}/c^2$ )	45
Sign. ( $m>0.15 \text{ GeV}/c^2$ )	<b>101667 +/- 2144</b>
Eff. Sign. ( $m>0.15 \text{ GeV}/c^2$ )	<b>1137 +/- 24</b>
B/S ( $m<0.15 \text{ GeV}/c^2$ )	0.21
Sign. ( $m<0.15 \text{ GeV}/c^2$ )	3.434 +/- 2e3
Eff. Sign. ( $m<0.15 \text{ GeV}/c^2$ )	2.417e6 +/- 1e3
Yield in (2.9-3.3 $\text{GeV}/c^2$ )	559 +/- 35

# The Next Steps

## 1. Ghost cut and pooling

Difference between Akiba/Matathias pool arises due to the pair cuts. Work in two directions:

- make the ghost cut as small as possible. The current cut removes more than 12% of the signal. Study the ghost cut! (DC, RICH, EMCAL?)
- study the Akiba/Matathias pool with HIJING

## 2. Electron ID with neural network

- Train NN on larger “high-mass” sample. Use  $\phi \rightarrow ee$  decay embedded in HIJING
- Use  $d\phi$  instead of  $E/p$  in the neural network eID

## 3. S/D rejection

- Will benefit from HBD run-by-run gain equilibration and module to module gain equilibration
- Train another neural network for S/D separation and compare with the current approach